

STRATEGY and TACTICS for Smallpox Eradication

HARALD FREDERIKSEN, M.D., M.P.H., D.T.M.&H.

THE THREAT of smallpox, increasing with the speed and volume of international travel, is indicated by the current experience of several European countries. Five persons incubating smallpox traveled from Pakistan to Great Britain within a period of 5 weeks. All five escaped immediate detection on arrival. Despite emergency measures, the current importations of smallpox have already given rise to 8 outbreaks in Great Britain, resulting in 63 indigenous cases, 18 of which have ended fatally, up to the time of writing.

This alarming experience indicates that nations which have escaped importations of smallpox may owe their good fortune to lesser volume of air travel from the endemic foci rather than the international system of quarantine. International travelers incubating smallpox can enter any country, even the United States, by presenting a valid certificate of vaccination. The crux of quarantine is the inspection of vaccination certificates, which are least reliable where there is most smallpox. Certainly, one cannot expect to discover smallpox incubating at the time of arrival. In fact, the importation of the exotic disease is usually not recognized until secondary or tertiary cases arise. In many countries where the system of epidemic intelligence and countermeasures are not as effective as in Great Britain, reintroduction of smallpox may not

be noted until a major epidemic results in the reestablishment of endemic smallpox, requiring a campaign to interrupt transmission again.

The Crux of the Problem

Once the major killer of mankind, smallpox survives only by sufferance. The burden of control, rather than the vestiges of the disease, has become the problem.

Smallpox control has been a patchwork of parochial policies ranging from suppression to palliation of endemic smallpox. The parochial concept of control, perpetuating vaccination where there is no smallpox and ignoring smallpox beyond the arbitrary confines of action, is pennywise and pound foolish.

Providing less than absolute protection solely for the people of the United States for a single generation will cost more than the eradication of the sources of smallpox from the world, ending the otherwise unending costs of control along with the threat of the disease. For the sake of economy as well as humanity, successive World Health Assemblies annually reiterate the urgency and the feasibility of smallpox eradication.

Concept of Eradication

Eradication of smallpox is the extinction of the virus by the synchronization of vaccination, rendering the disease nonexistent and control superfluous.

The term "eradication" has been applied to the interruption of transmission in one country which has been maintained for a number of

Dr. Frederiksen is program officer, Division of International Health, Public Health Service, and in 1957-58 was director of the Inter-American Cooperative Health Service in Bolivia.

years. Thus, the Directing Council of the Pan American Health Organization has approved the following criteria for eradication: "From a practical point of view, countries in which smallpox is endemic may consider the disease eradicated when no new cases of smallpox occur during the 3 years immediately following the completion of a suitable vaccination campaign" (1).

Qualifying the concept of eradication by introducing into the criteria political boundaries not recognized by the disease would render the global concept of eradication synonymous with the parochial concept of control. Only by synchronizing the interruption of transmission in all countries would the interruption of transmission in one country become an integral part of the eradication of smallpox.

The Inter-Regional Smallpox Conference organized by the World Health Organization agreed "that the eradication of smallpox can not be considered on the basis of individual territories" and "that eradication of smallpox from the world can only be achieved by global action to render the disease nonexistent and its control redundant," and the conference "therefore urges the health administrations of all countries in endemic regions to synchronize their eradication campaigns" (2,3).

Operational Considerations

Smallpox has disappeared where vaccination and epidemiologic measures are routine. Where health services are lacking and, as a consequence, routine measures are not feasible, mass vaccination has interrupted the transmission of smallpox.

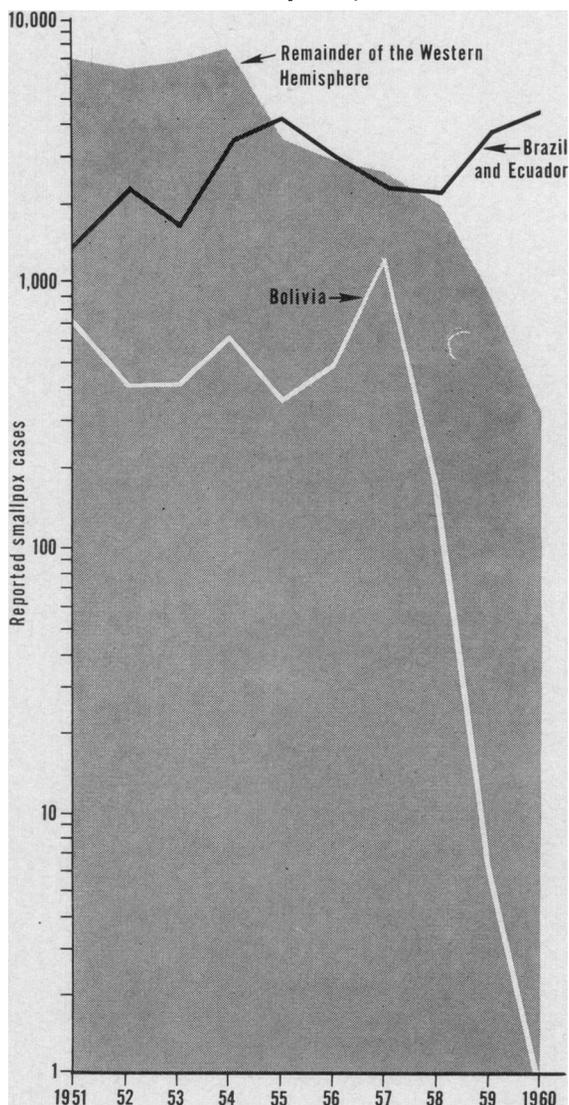
For some time to come, eradication will only be achieved by the synchronization of campaigns producing sufficient immunity to interrupt transmission wherever circumstances have frustrated routine vaccination and epidemiologic measures of control.

The experience of Bolivia demonstrates the utility of mass vaccination and the futility of routine vaccination where health services are lacking (4). Endemic smallpox had persisted without diminution, although the number of vaccinations reported in a course of a few years equalled the number of inhabitants. Evidently,

the most accessible sectors of the population were being repeatedly vaccinated, and others were not being vaccinated at all. Failure was compounded by the use of thermolabile vaccine in an area where facilities for the conservation of the potency were limited.

Before the start of mass vaccination in the latter part of 1957, Bolivia was experiencing the highest attack rate for smallpox in the Americas. Mass vaccination of 84 percent of the population (with 96 percent primary reactions in samples of primary vaccinations) immunized about 80 percent of the population by

Figure 1. Cases of smallpox reported in the Western Hemisphere, 1951-60



SOURCE: Pan American Sanitary Bureau.

Figure 2. Prevalence of pockmarked individuals in the age group 40 or more years, by province, Bolivia, 1957-59



Figure 3. Density of inhabitants per square kilometer, by province, Bolivia, 1950



SOURCE: Census of Bolivia, 1950.

1959. Only one case of smallpox was reported in 1960 and no further cases up to the time of writing in 1962 (fig. 1). Transmission of smallpox appears to have been interrupted at the cost of 5 cents (U.S.) per capita. The efficacy, efficiency, and economy of the mass vaccination in Bolivia are attributed principally to the following factors:

- Organization of the campaign as a dependency of the autonomous Inter-American Cooperative Health Service, jointly supported by the governments of Bolivia and the United States of America.
- Organization, administration, and logistics of the campaign specifically designed to facilitate mass vaccination by mobile teams.
- Separation of the functions of vaccination, supervision of vaccination, inspection of results, routine analysis of statistics, and epidemiologic assessment.
- Uniform methods specified in a manual of procedures.
- Job descriptions for all categories of personnel.
- Adequate provision of funds, equipment, vaccine, and transportation.
- Contractual employment of auxiliary per-

sonnel subject to professional supervision and probation.

- Merit system, pay scale, allowances, uniforms, and field equipment to enhance efficiency, morale, and discipline.
- Organization of vaccinators into motorized teams and concentration of the teams in one area at a time to increase mobility, facilitate supervision, and shorten supply lines.
- Advance planning of itineraries of 3 to 4 weeks' duration followed by 1 week of rest and preparation for the next itinerary.
- Start of mass vaccination in the main streams of infection.
- House-to-house vaccination of all, regardless of the history of vaccination or smallpox, excepting only the newborn, the acutely ill, and those with generalized eczema.
- Exclusive use of lyophilized vaccine to insure potency at the time of vaccination.
- Elimination of the prior application of alcohol or other virucide to the site of vaccination.
- Use of common pins as sterilized, disposable vaccinostyles.
- Use of the single-scratch vaccination technique, which is readily taught and learned, provides visible evidence of vaccination, facilitates

the uniformity of technique, and is faster than other methods but equally effective.

- Use of an indelible dye in lieu of vaccination certificates and cumbersome records for a more rapid, reliable control of the quantity and quality of vaccination.

- Routine inspection of sample households for evidence of quantity and quality of vaccination about 9 days after vaccination.

- Health education and public information designed to reach even the illiterate.

Epidemiologic Considerations

The realization that lack of reporting hampers both planning and evaluation of the interruption of transmission led to surveys of the prevalence of pockmarked individuals in Iran and Bolivia (4, 5). It was found that inspection for pockmarks could readily and economically be incorporated in campaigns of mass vaccination at the time of the inspection of takes. It was concluded that surveys of the prevalence of pockmarks provide a more complete and accurate record of the endemicity of smallpox. At times pockmarks are the only record of smallpox.

The terms "pox rate" and "pox survey" have been proposed for the prevalence and survey of the prevalence of pockmarked individuals (2).

The highest proportion of pockmarked individuals was found in the most densely populated area of Bolivia (figs. 2 and 3). There was a high correlation between population density and the proportion of pockmarked individuals in 10 provinces on the highland plateau of Bolivia, which are homogeneous in respect to topographic, climatic, economic, social, cultural, and racial factors. The correlation was high in all age groups and remained high when the history of vaccination was held constant (tables 1 and 2).

The pox survey indicates that the most densely populated area of the focus tends to be the epicenter of endemic smallpox. This area retains the greatest endemic potential once transmission is interrupted unless it is given priority in the maintenance of immunity until the eradication of the sources of possible reinfection.

The findings that smallpox endemicity and, therefore, the critical level of immunity vary with population density may have implications for mass vaccination in more densely populated areas. Although it has often been stated that endemic smallpox will die out when 80 percent of every sector of the population is successfully vaccinated within a period of 5 years, such a proportion may not provide much margin over

Table 1. Prevalence of pockmarked and unvaccinated individuals, by age group and population density in 11 provinces of the highland plateau of Bolivia, 1958

Province	Sample	Percent pockmarked (p) and not vaccinated (nv), by age group (years)														Population density per sq. km.
		All ages (not age adjusted)		0-4		5-9		10-19		20-39		40 or over		All ages (age adjusted) ¹		
		p	nv	p	nv	p	nv	p	nv	p	nv	p	nv	p	nv	
Manco Kapac	179	31.3	35.1	5.0	55.0	8.5	23.4	21.7	19.6	50.0	38.9	76.6	60.0	32.5	39.4	60.3
Comacho ²	1,637	30.1	49.4	1.6	10.6	10.6	23.5	23.5	45.9	45.9	55.8	55.8	27.5	27.5	32.5	32.5
Omasuyos	997	21.5	35.8	.6	56.1	6.9	14.7	16.8	20.4	37.1	42.7	49.1	55.1	22.1	37.8	31.4
Los Andes	1,525	14.6	34.4	.4	68.4	2.6	16.3	5.1	23.0	24.5	28.9	46.1	52.0	15.7	37.7	30.9
Dalence	1,786	5.1	30.9	.3	77.8	1.6	31.9	3.3	8.5	13.5	17.0	19.0	23.8	7.5	31.8	13.6
Ingavi	1,384	13.7	29.8	0	66.2	2.7	18.5	5.9	9.5	28.0	28.9	38.7	52.4	15.1	35.1	12.2
Aroma	812	12.7	30.7	1.0	66.7	3.3	40.1	7.6	6.3	28.3	37.0	27.7	38.3	13.6	37.7	9.5
Abaroa	130	9.2	47.7	0	95.5	0	72.2	11.1	48.1	16.3	18.6	10.0	35.0	7.5	53.9	5.1
Pacajes	1,849	9.5	35.0	0	73.2	2.0	33.9	5.5	23.5	16.9	26.2	40.0	62.9	12.9	43.9	4.8
Poopó	320	6.3	17.2	0	60.0	1.5	16.9	.7	5.4	18.8	30.1	27.8	27.8	9.8	28.0	4.8
Sabaya	476	3.6	35.1	0	82.8	0	48.3	0	14.2	6.9	19.6	15.6	35.9	4.5	40.2	.6

¹ Age adjusted by averaging age-specific rates for the age groups: 0-4, 5-9, 10-19, 20-39, and 40 and over.

² Rates for Comacho not included in table 2 correlations because of the lack of comparable data on vaccination history.

the level of immunity required for the interruption of transmission in more densely populated areas.

Therefore, it may be advisable, if not essential, to immunize a greater proportion of the population in the more densely populated areas. Loss of immunity through passage of time and birth of susceptibles can be minimized by completing the cycle of mass vaccination more rapidly. The level of immunity can be increased by repeating the cycle of mass vaccination and eliminating any interval between the cycles. Moreover, the exclusive use of lyophilized vaccine will tend to insure immunization of those vaccinated.

While serving a number of purposes, the pox survey may prove to be of greatest value in the confirmation of the interruption of transmission. In areas where completeness and accuracy of reporting is doubtful, interruption of transmission might be presumed in the absence of reported cases for a period of time exceeding the observed interepidemic period but would be confirmed by the absence of pockmarks in a survey of those born since the cycle of mass vaccination.

When reporting is deficient, routine vaccination would probably be insufficient to maintain an adequate level of immunity as long as the threat of reinfection persists. Thus, maintenance as well as confirmation of the interruption of transmission after one cycle of mass vaccination would require another cycle of mass vaccination, combining inspection of children for pockmarks with vaccination and inspection of takes.

Timing of Eradication

Endemic smallpox is rapidly being suppressed in all but two countries of the Western Hemisphere (fig. 1). Action befitting the "Alliance For Progress" would rid the Western Hemisphere of endemic smallpox within a decade. But enthusiasm is tempered by the realization that eradication requires all countries to synchronize vaccination, even though some countries may not consider a sanctuary for smallpox within the national boundaries as the major health problem from the national point of view. With the launching of the gigantic campaign for mass vaccination of the popula-

Table 2. Correlations between the proportion of pockmarked individuals (x_1), proportion of unvaccinated individuals (x_2), and population density per square kilometer (x_3) in 10 provinces of the highland plateau of Bolivia, 1958

Coefficient of correlation	Age groups (years)		
	5-19	20 or over	All ages
r_{12} -----	-.03	.86	-.06
r_{13} -----	.85	.91	.92
r_{23} -----	-.28	.64	-.07
$r_{12.3}$ -----	.41	.86	.03
$r_{13.2}$ -----	.90	.91	.93

SOURCE: Data in table 1.

tion in India, mass vaccination in the residual foci of infection can no longer be considered a task too large, too difficult, or too costly.

Failure to synchronize vaccination will result in ping-pong smallpox and prolong vaccination in countries presently free of the disease until all nations are willing to protect other peoples as well as their own. Where interruption of transmission requires mass vaccination, repeated cycles of mass vaccination would be required to maintain immunity until transmission is interrupted worldwide. Any delay in the eradication of smallpox would be costly.

It may prove useful, if not essential, for the World Health Assembly to consider and adopt a specific timetable for the synchronization of national campaigns in the endemic foci.

Some countries may require supplementation of resources to launch effective campaigns at the opportune time. Since the national campaigns would form integral parts of the eradication of smallpox, all countries may expect returns infinitely greater than a fair share of the costs, a few cents per capita. The World Health Organization provides a mechanism for governments to share funds, equipment, vaccine, and personnel, and to participate as partners in the planning, execution, and evaluation of a worldwide effort for the eradication of smallpox.

Conclusions

The cost of smallpox control, rather than the vestiges of the disease, is the crux of the problem. The parochial concept of control, ignor-

ing smallpox beyond arbitrary confines of action and perpetuating vaccination where there is no smallpox, is pennywise and pound foolish.

Less than absolute protection solely for the people of the United States for a single generation will cost more than the eradication of the sources of smallpox from the world, ending the otherwise unending costs of control along with the threat of the disease.

The transmission of smallpox can be interrupted by mass vaccination with a thermostable vaccine wherever routine vaccination is neither effective nor feasible. The critical level of immunity will vary with the population density. Smallpox will be eradicated by the synchronization of such efforts.

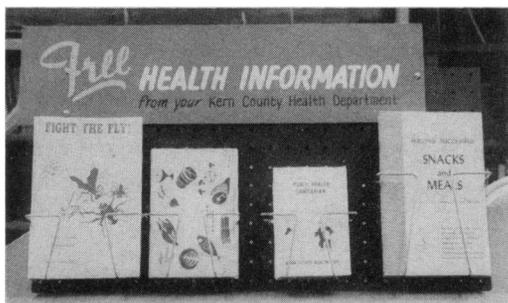
Where reporting is lacking, interruption of transmission might be presumed in the absence of reported cases but may be confirmed by "pox surveys." Inspection for pockmarking of those born since a previous cycle of mass vaccination can readily and economically be incorporated in subsequent cycles of mass vaccination at the time of vaccination and inspection of takes.

The World Health Organization and the World Health Assembly provide mechanisms for the worldwide sharing and timing of national efforts, which would form integral parts of the eradication of smallpox.

REFERENCES

- (1) Directing Council, Pan American Health Organization, Regional Committee of the World Health Organization: Provisional precis minutes of the eleventh plenary session. Washington, D.C., October 1961. Mimeographed.
- (2) Frederiksen, H.: Eradication versus control of smallpox. Presented at the WHO Inter-Regional Smallpox Conference, New Delhi, India, November 1960. Mimeographed.
- (3) Report of the WHO Inter-Regional Smallpox Conference, New Delhi, India, November 14-19, 1960. WHO/Smallpox/17. March 7, 1961. Mimeographed.
- (4) Frederiksen, H., Torres Muñoz, N., and Jauregui Molina, A.: Smallpox eradication. *Pub. Health Rep.* 74: 771-778, September 1959.
- (5) Frederiksen, H., and Sheehy, J. P.: Smallpox control by mass vaccination with dried vaccine. *Pub. Health Rep.* 72: 163-172, February 1957.

A Method for Distributing Information Materials



The Kern County Health Department in California has developed a system facilitating the distribution of publications.

The method is based on an extremely simple, flexible, tabletop pamphlet rack (shown above). The racks, filled with appropriate

information materials, have been placed in the offices of physicians and dentists and in hospital waiting rooms. The racks are regularly filled by a health department staff member. In this way, health information is brought to many people who are not often reached by the health department. The system is periodically reviewed and evaluated in order to make best possible use of materials available.

The racks are simply constructed from a peg board, two wooden triangles for rear support, light metal fixtures, and a sign. The cost of materials is about \$1.50 per rack. The racks may be placed on counter tops or attached to walls.—GLENN I. HILDEBRAND, M.P.H., *director, health education division, Kern County Health Department, Bakersfield, Calif.*